

Reservoir Characterization of Aquifers & Monitoring CCS Using Seismic Data

Bengt Larssen
WesternGeco

Marcia Couëslan
Schlumberger Carbon Services

Schlumberger Private



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Outline

2

- Challenges
- Surface seismic data
- VSP Data
- Integration
- Conclusions

Introduction

3

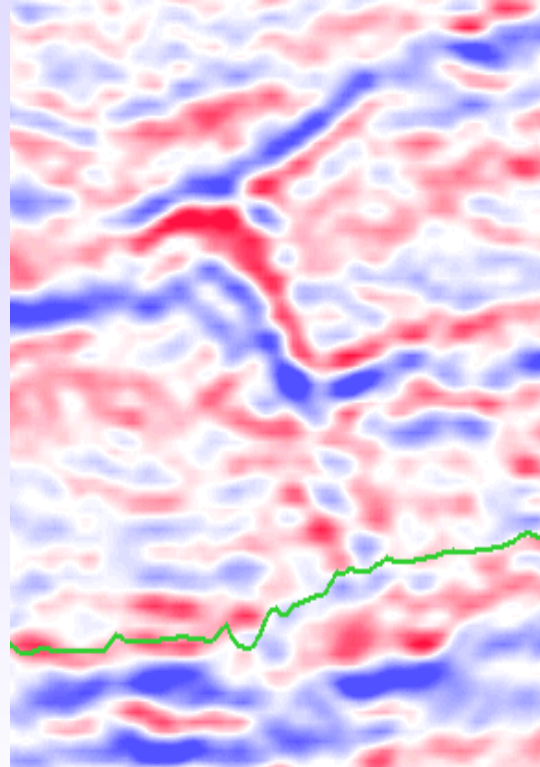
- Seismic data for Reservoir characterization
 - Building initial static (geologic) model
 - Dynamic (reservoir) model - monitoring the injected CO₂ and verify containment
- Seismic data will reduce risk by identifying
 - Leakage accumulations
 - Changes in storage capacity
 - Fault re-activation

High Resolution Data & Lithology

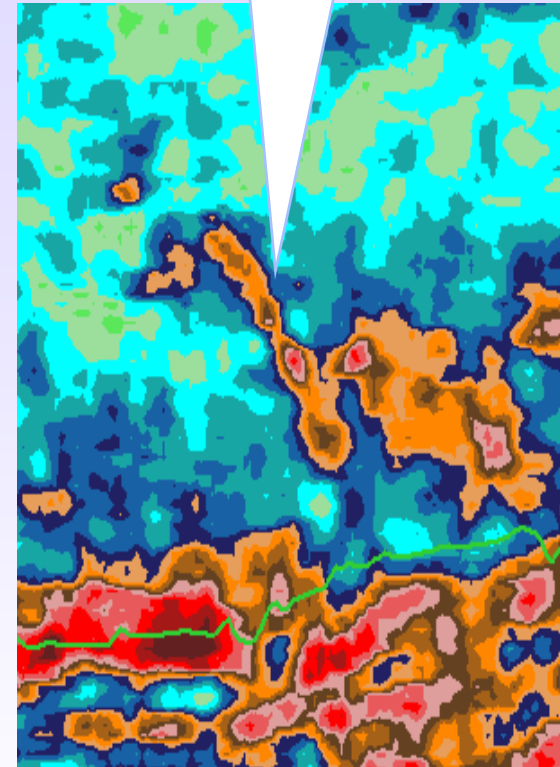
4



Rocks at Outcrop



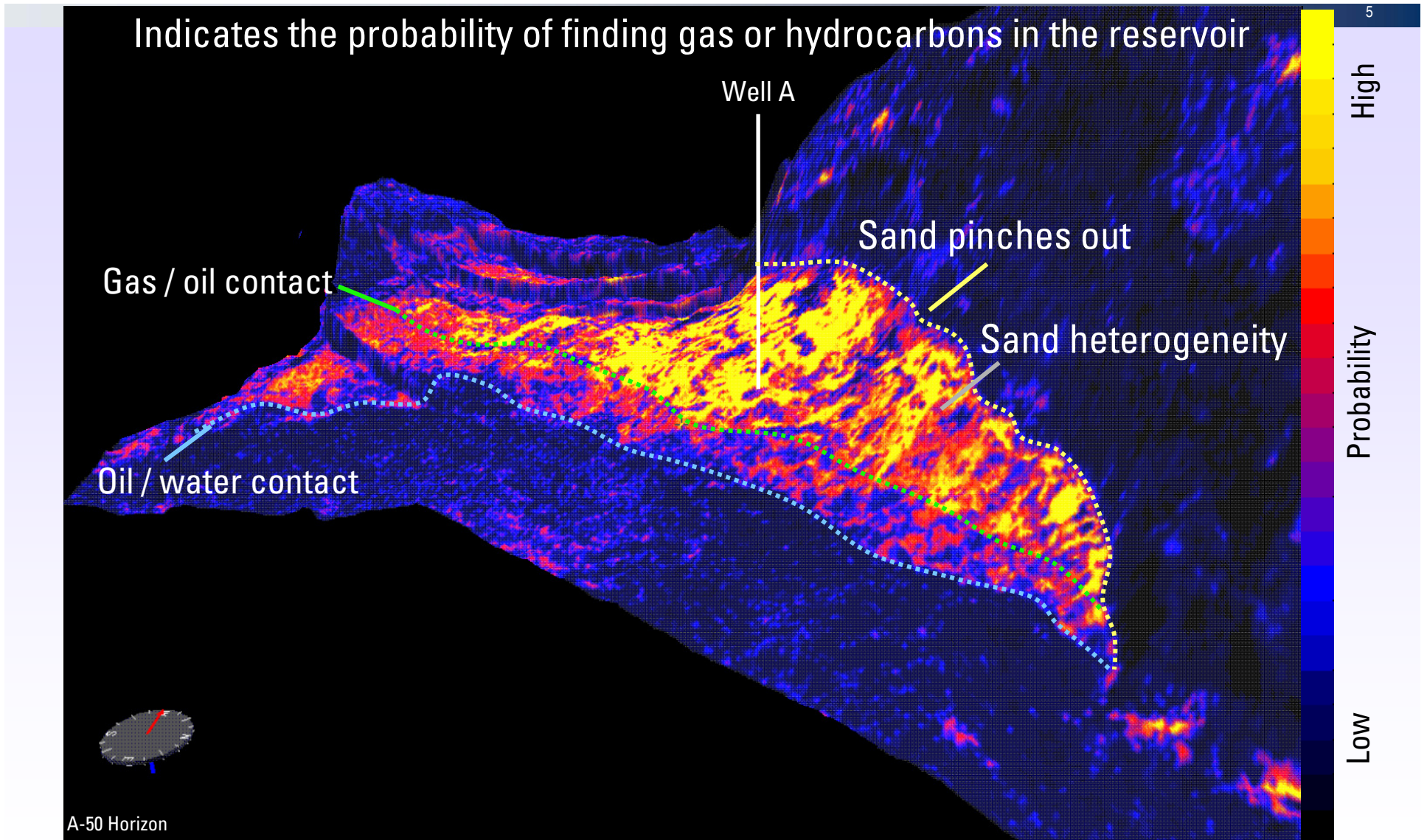
Q Data



**Geobody
10m x 80m**

Lithology Prediction

Getting the “map” right from seismic data



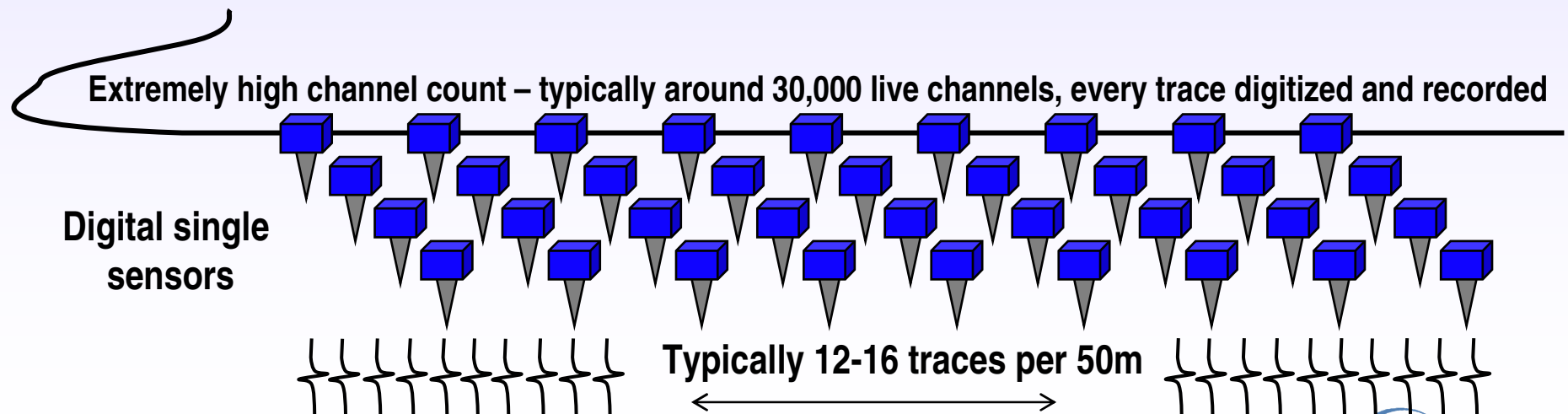
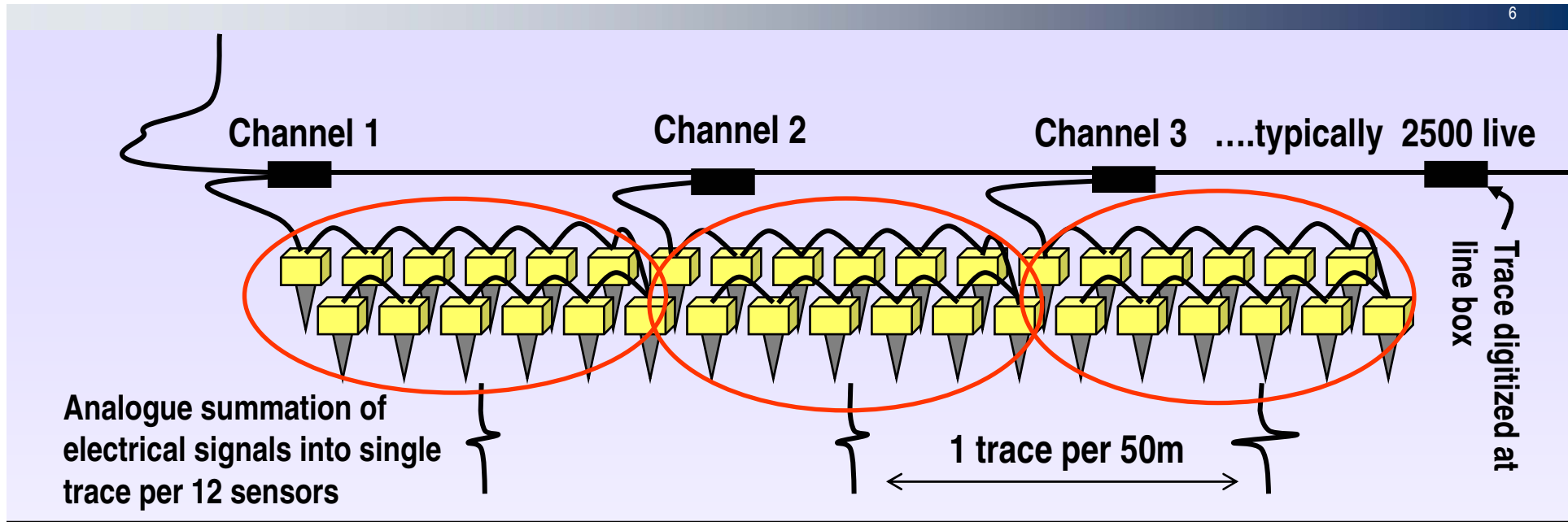
Source: , Case Study on improved Reservoir Characterization through Seismic Inversion Leading Edge Apr 2004

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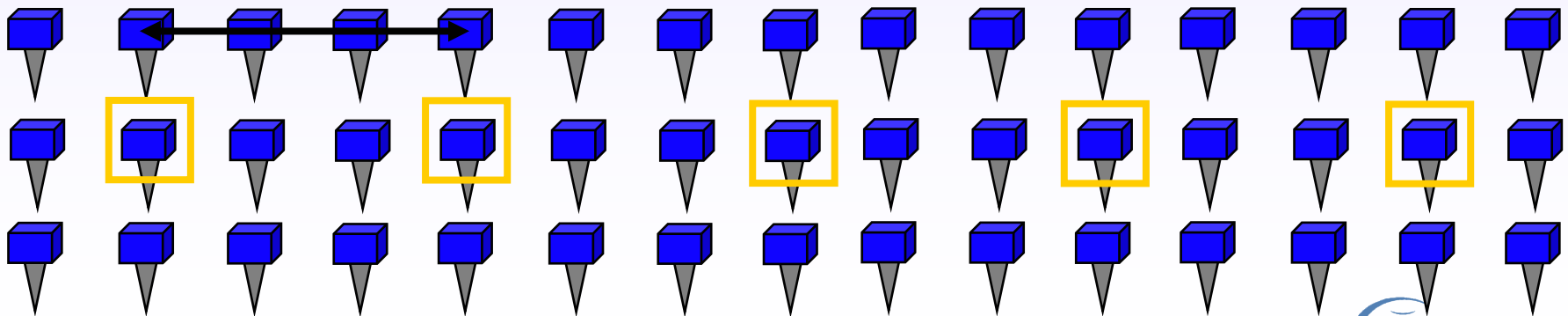


Conventional vs. Q Seismic Data

6

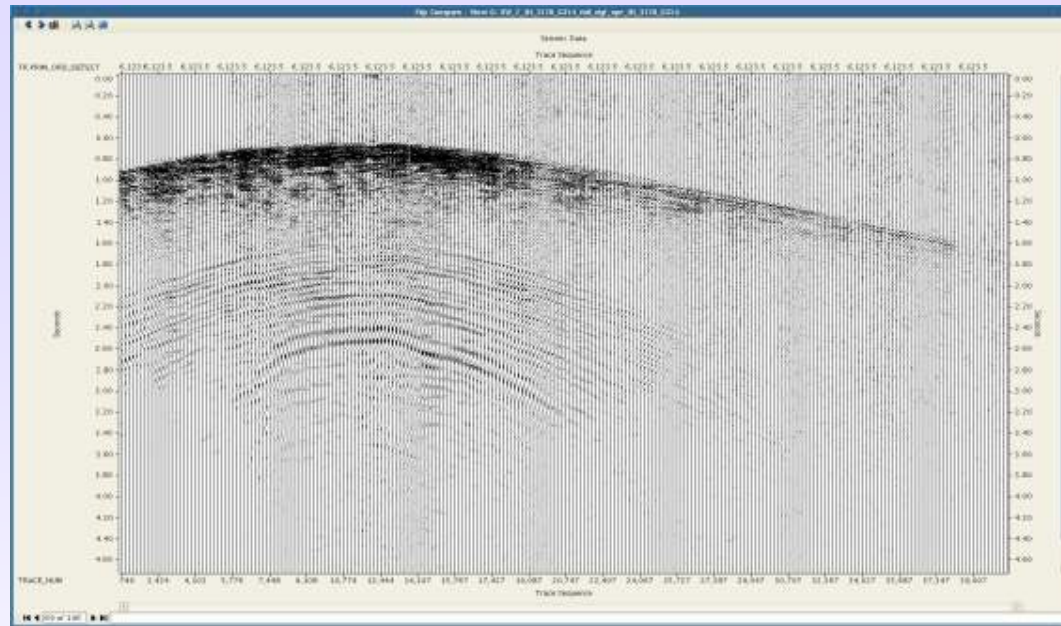


7

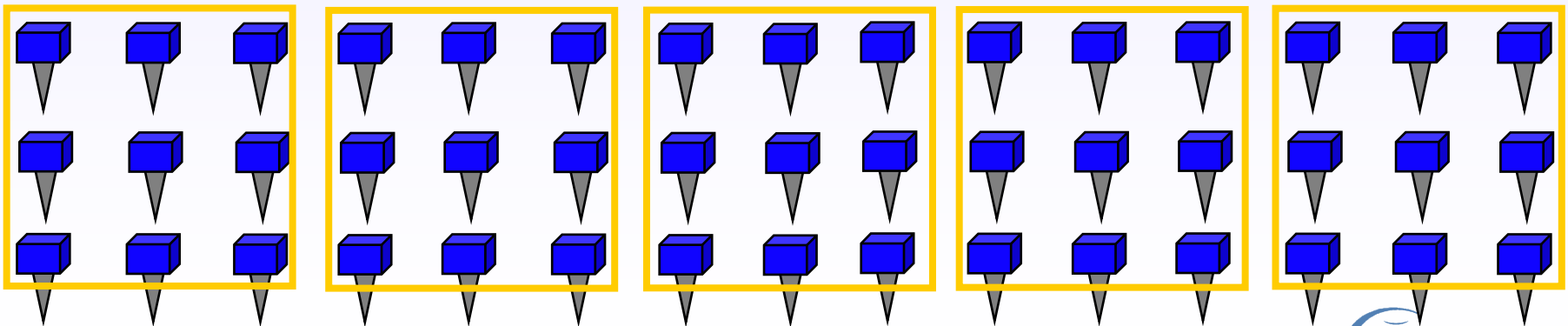


Q Data: 9 Single Sensor Traces Summed

8

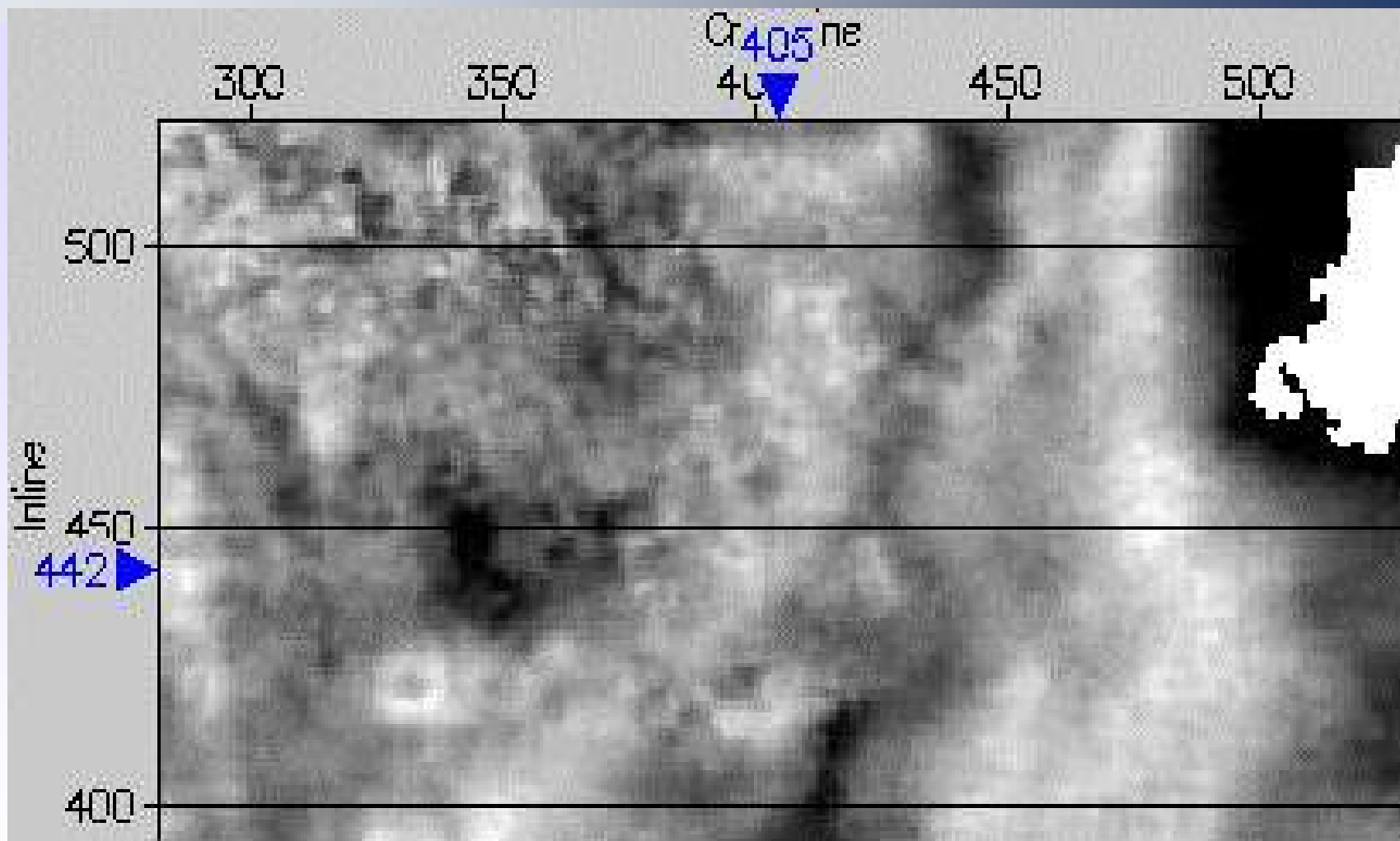


Ambient noise suppression applied



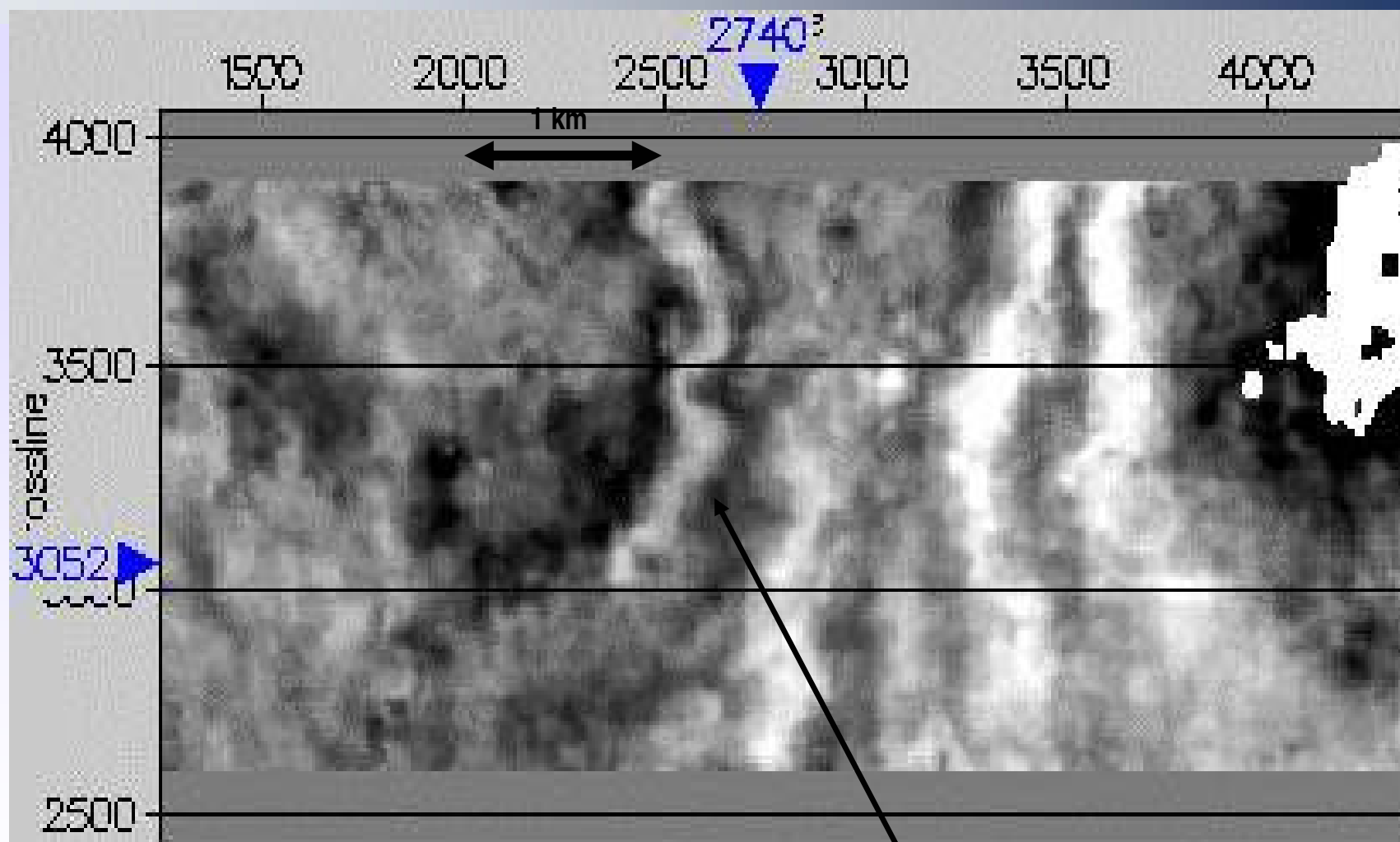
Data Comparison – Conventional

9



Data Comparison – Q-Land

10

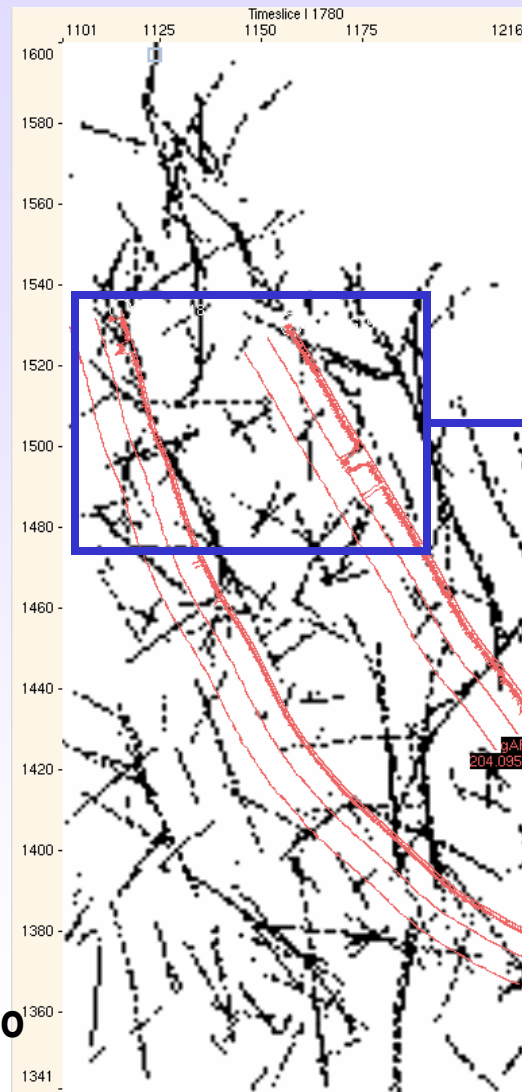


Sand channel ~200 m wide

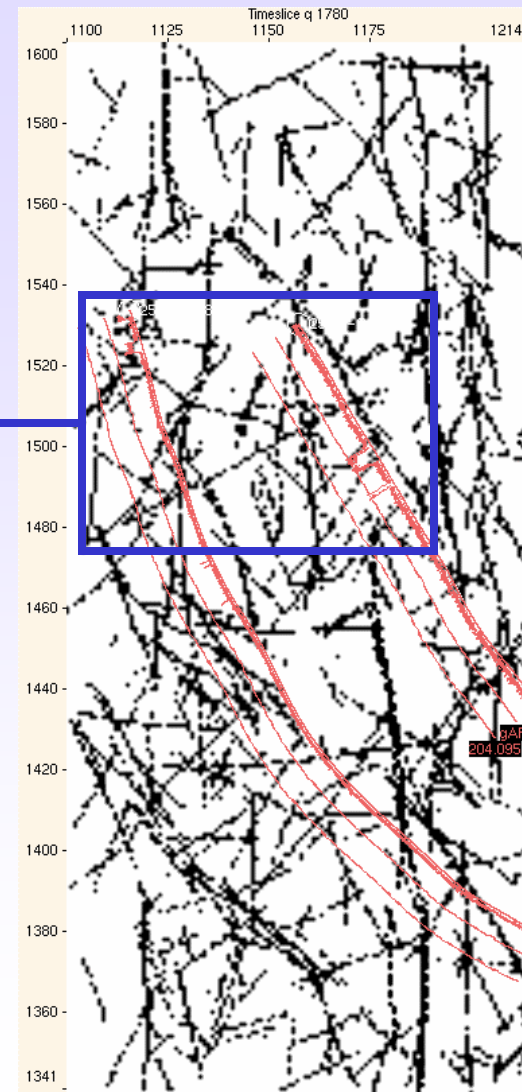
Fault & Fracture Characterization

11

**Non-Q
Fault ID
on
timeslices**



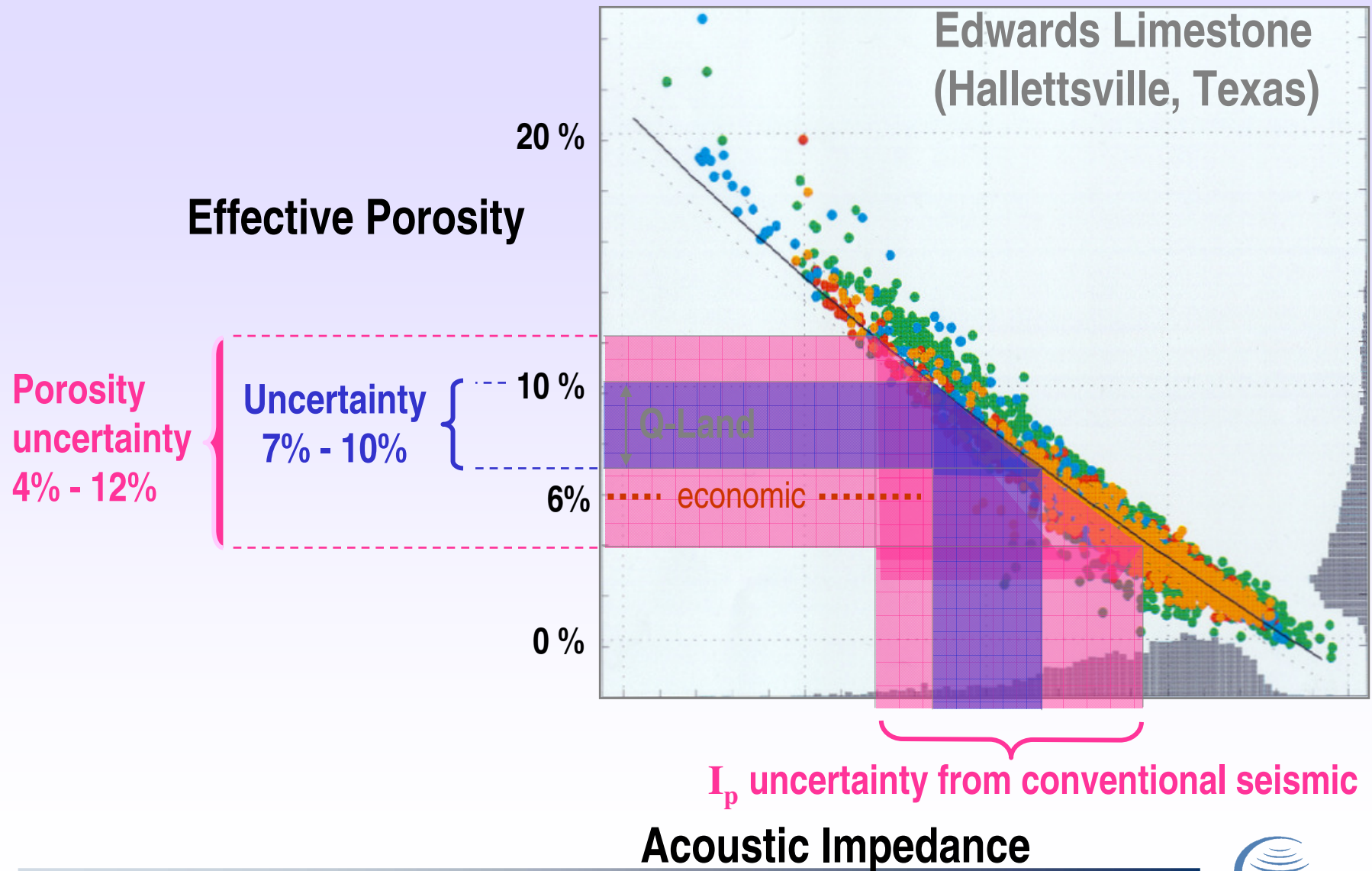
**Q
Fault ID
on
timeslices**



Courtesy of Hydro

Reducing Uncertainty

12



Feasibility/Survey Evaluation and Design

13

- **Modeling**

- Rock physics
- Log-based fluid substitution
- Wedge modeling
- Simulation to seismic
- Repeatability

- **Measurement**

- seismic
- Analogs
- logs

- **Impact/Measures of Success**

- Technical
- Business
- Economic

- **Will 4D work?**

- 4D signal
- 4D repeatability

- **Is 4D needed?**

- Uncertainty
- Unexplained events
- Decisions

- **Impact/Measures of Success**

- Technical
- Business
- Economic

Time-lapse Seismic Data

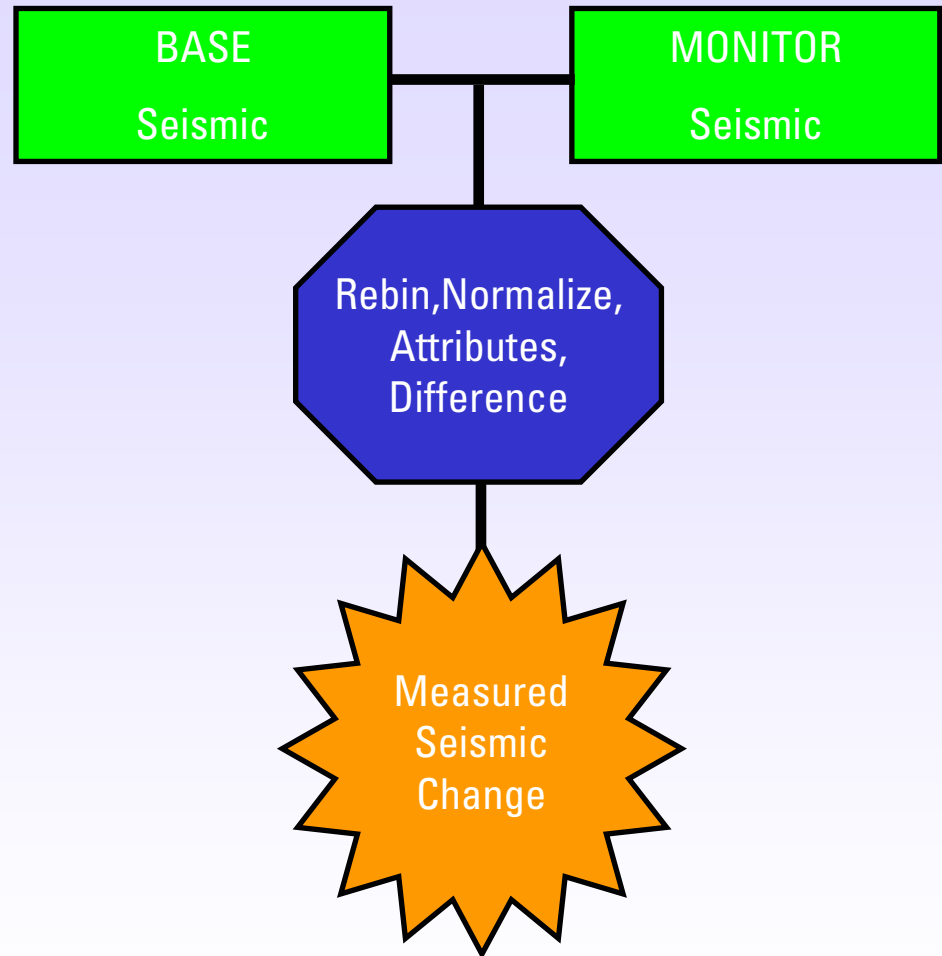
14

- Requires modeling to determine feasibility
- Multiple snapshots of the formation over time
 - Can monitor CO₂ flood in a formation
 - Identify leakage accumulations in overburden
 - Use to verify & update dynamic formation models
- Formation properties change with time which affects seismic response
 - Seismic velocities & associated traveltimes
 - Injected fluids cause amplitude changes
- High data repeatability is critical to success

4D Seismic - the Concept

15

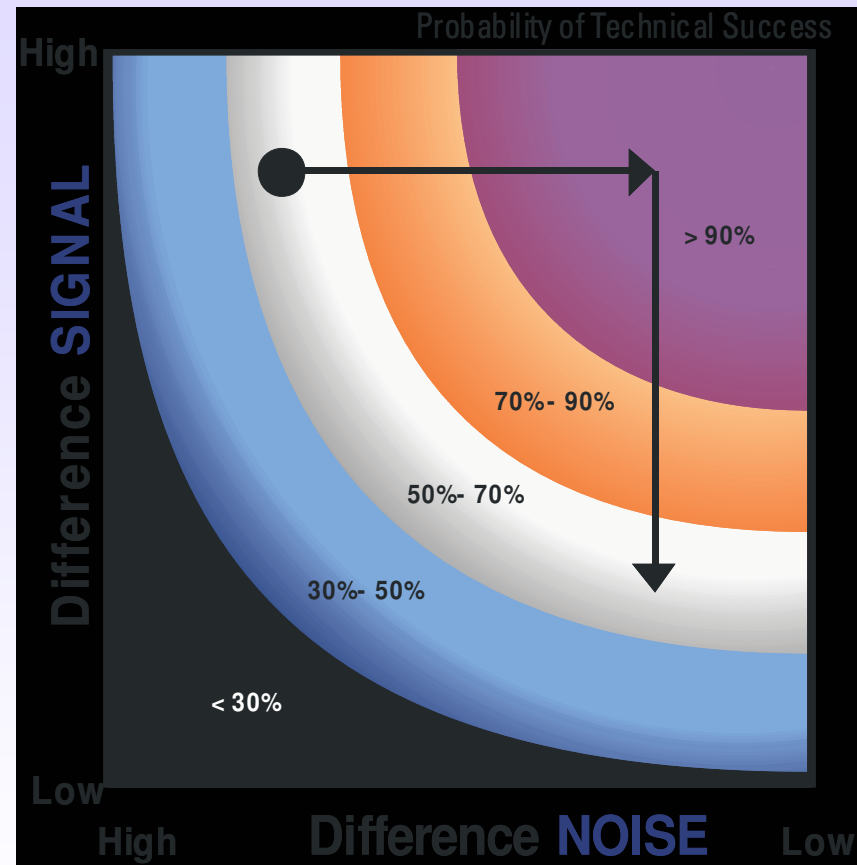
- Also known as Seismic Reservoir Monitoring or Time-Lapse Seismic
- Consists of 3D seismic surveys, repeated after intervals of production
- Successive surveys analysed for differences
- Observes changes in the reservoir and outside
- Available between & beyond the wells



4D Fundamentals

16

- **Reservoir** - define the problem, predict the reservoir changes, and decide how results will be used
- **Rock Physics** - the relationship between rock properties and acoustic measurements
- **Resolution** - our ability to detect the time-lapse changes we need to see, even if we can't resolve the event
- **Repeatability** - the fidelity of time-lapse seismic measurements in representing only reservoir property changes



4D Signal Inside a Reservoir

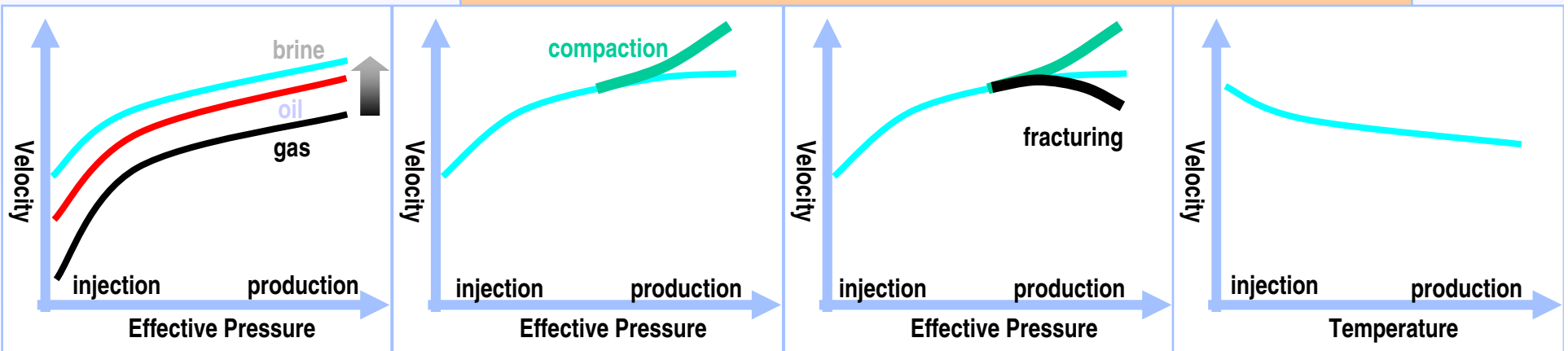
17

Δ saturation
Δ fluid type
Δ fluid pressure
Δ porosity
Δ temperature

overburden

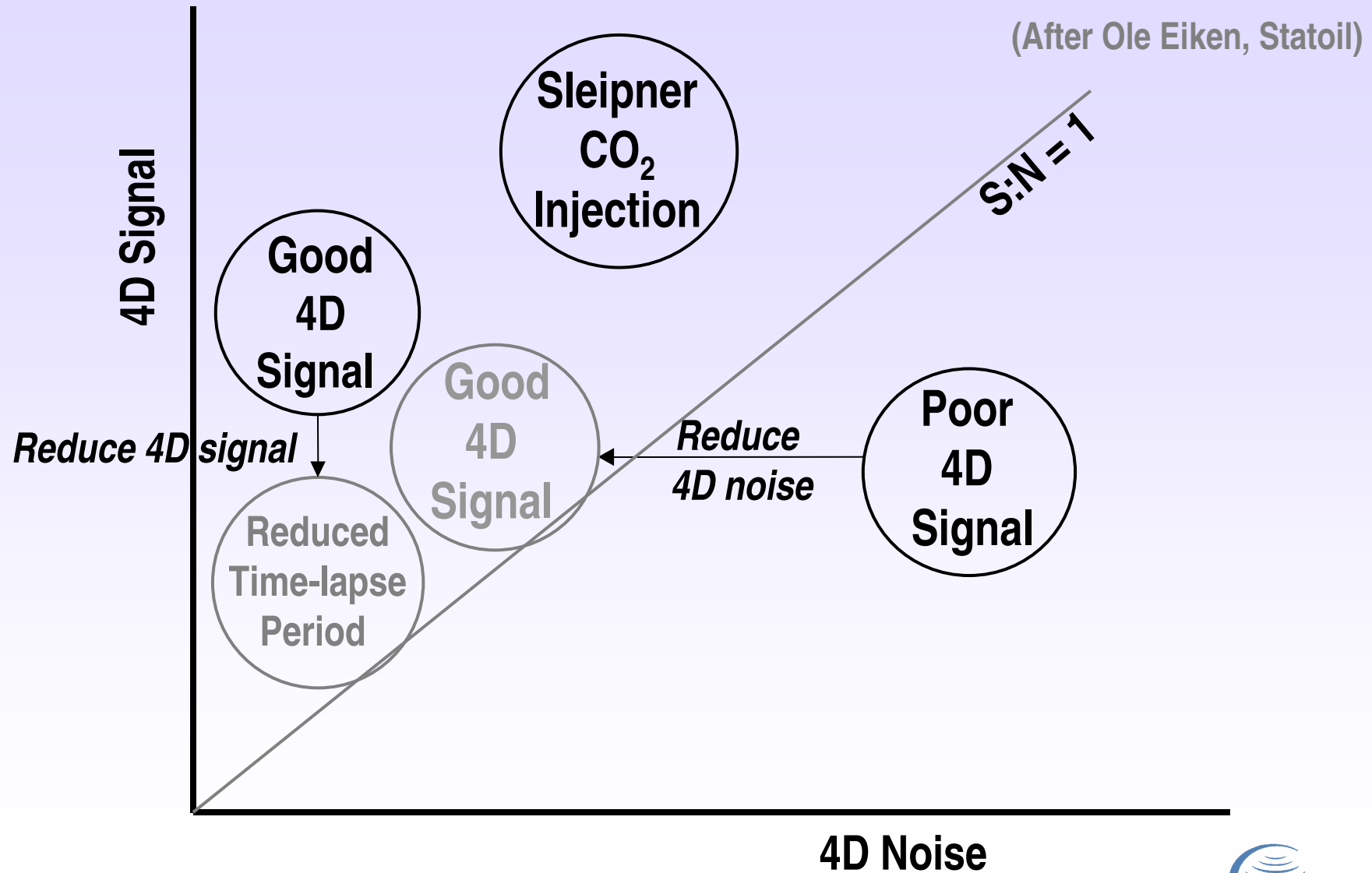
Reservoir rock

underburden



Time-lapse Signal & Time-lapse Noise

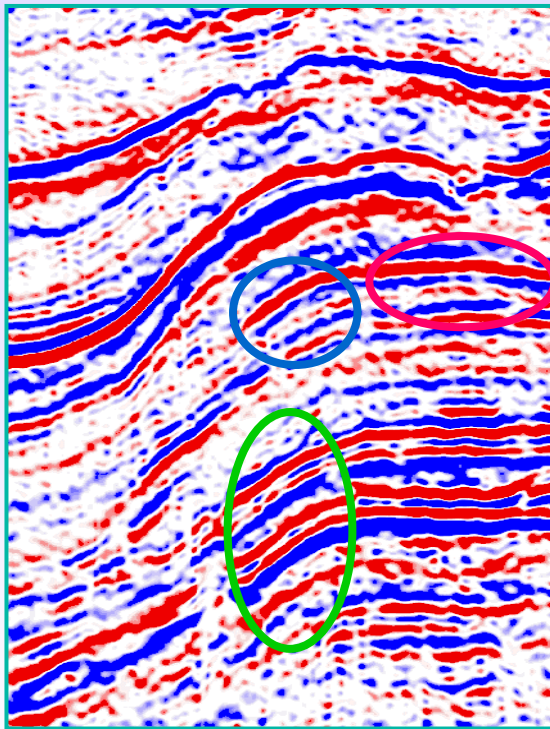
18



Repeatability Analysis

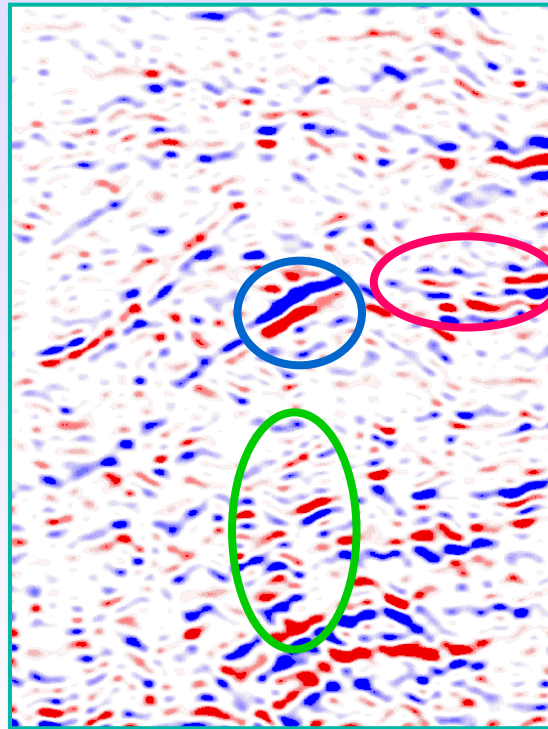
19

2003



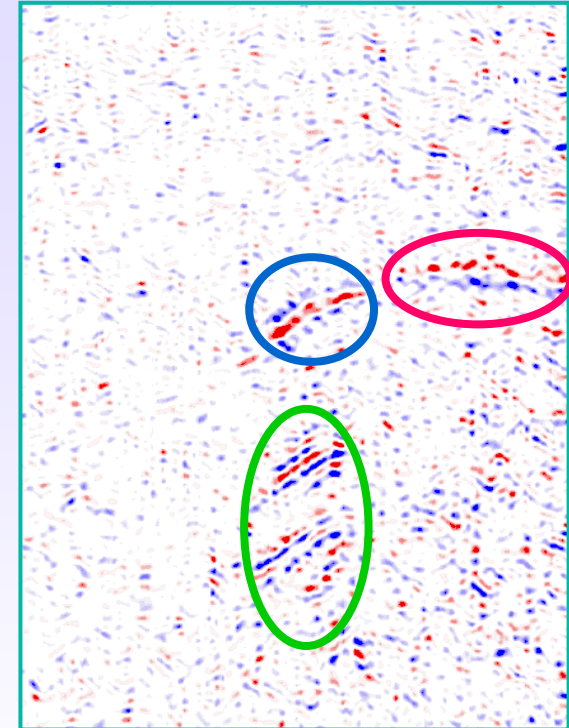
2003 final migration
in-line

1992 - 2003



Cross-matched processing
(conventional on Q-Marine)

2001 - 2003



Deterministic
processing (Q on Q)

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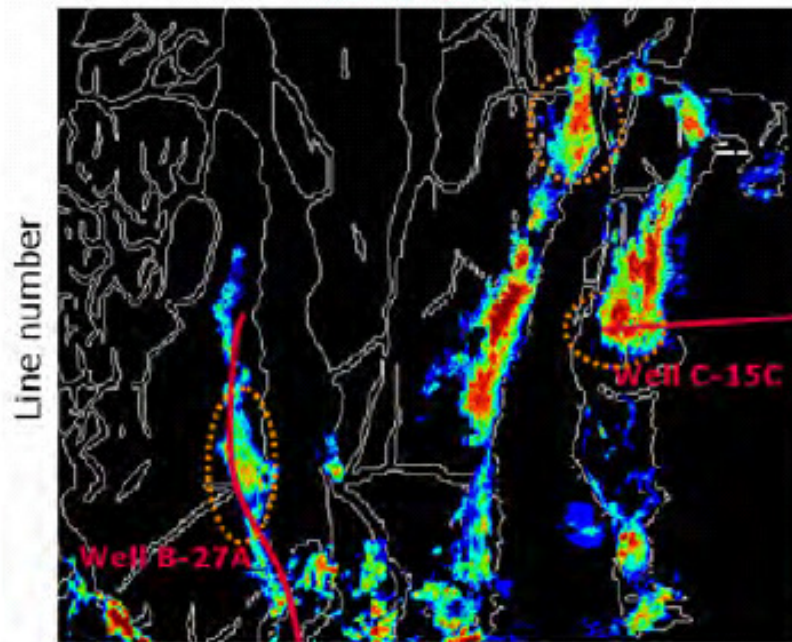
Map of Sw

20

Sw from ISIS

Thickness map of Soil > 0.5 (2003)

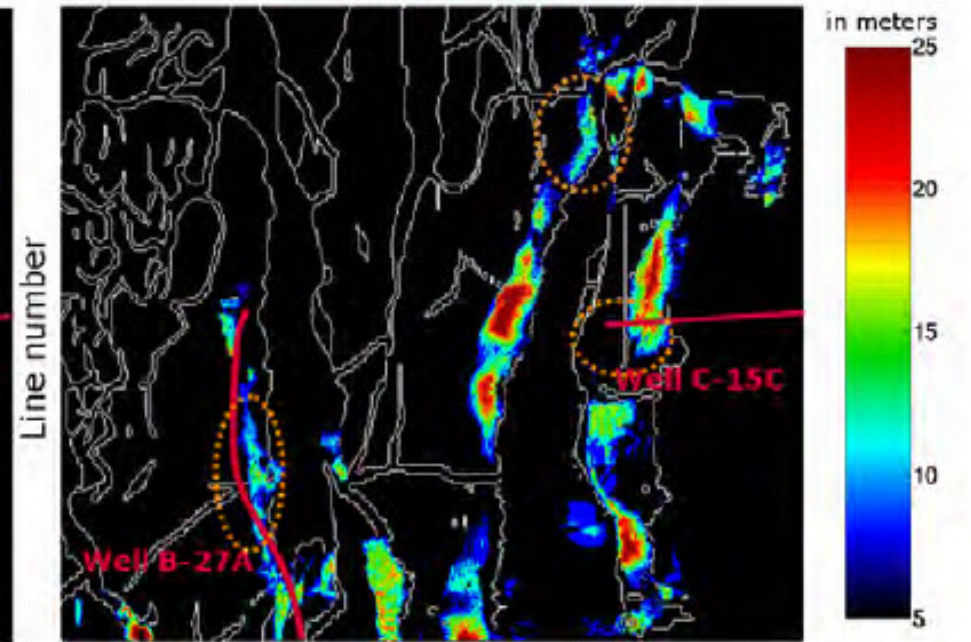
4D inversion



Reservoir model

Thickness map of Soil > 0.5 (2003)

Reservoir flow model



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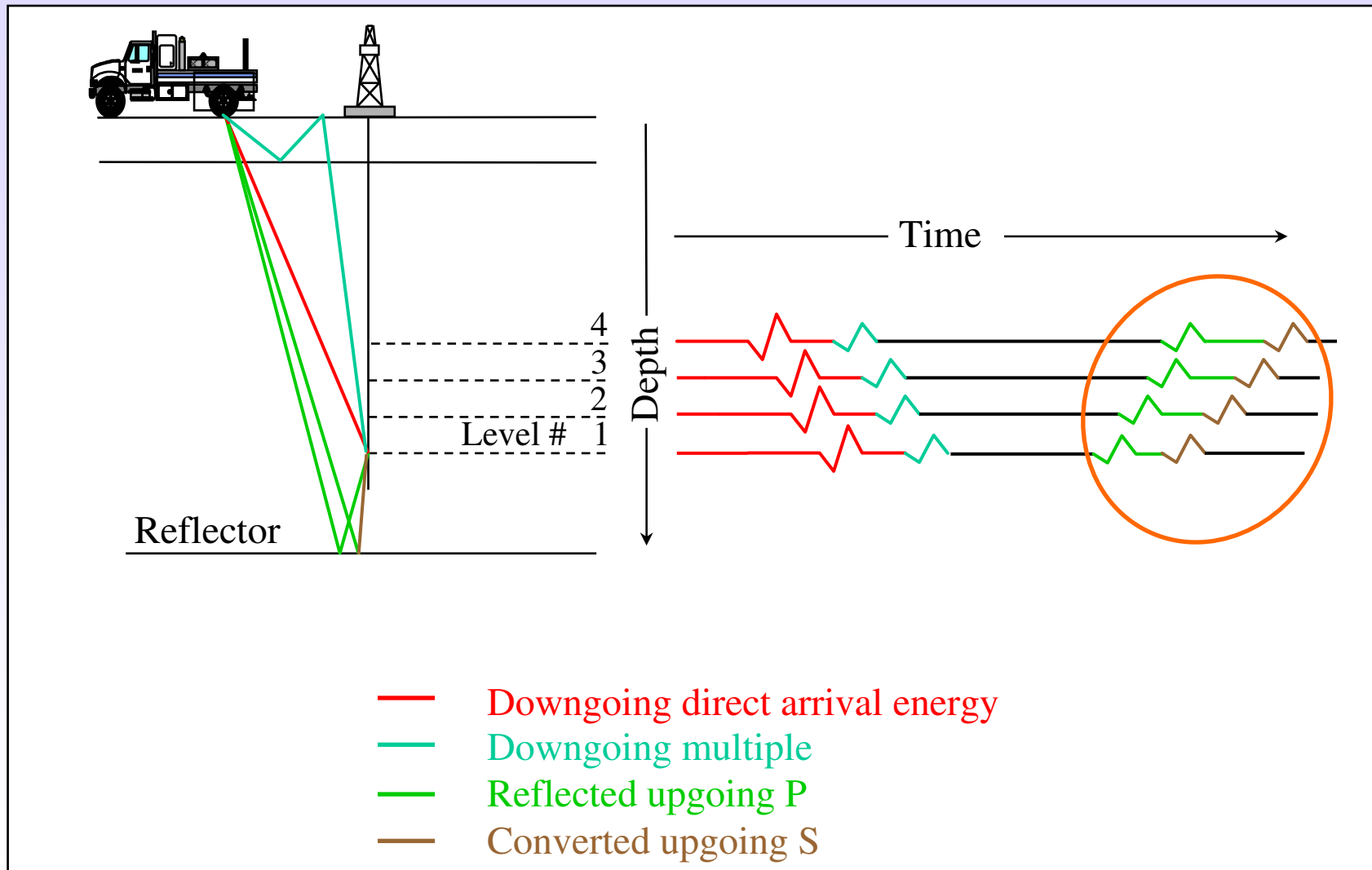
Advantages of VSP Data

21

- Higher frequency bandwidth than surface seismic data
 - Higher vertical & horizontal resolution around monitor well
- Provide a correlation between surface seismic data and well logs
- Parameters obtained during processing can be used to improve surface seismic imaging (Well Driven Seismic)
 - Velocity model, Q estimation, anisotropy analysis, multiple models and attenuation
- Permanent arrays
 - Ensure excellent data repeatability
 - Allows for passive seismic monitoring

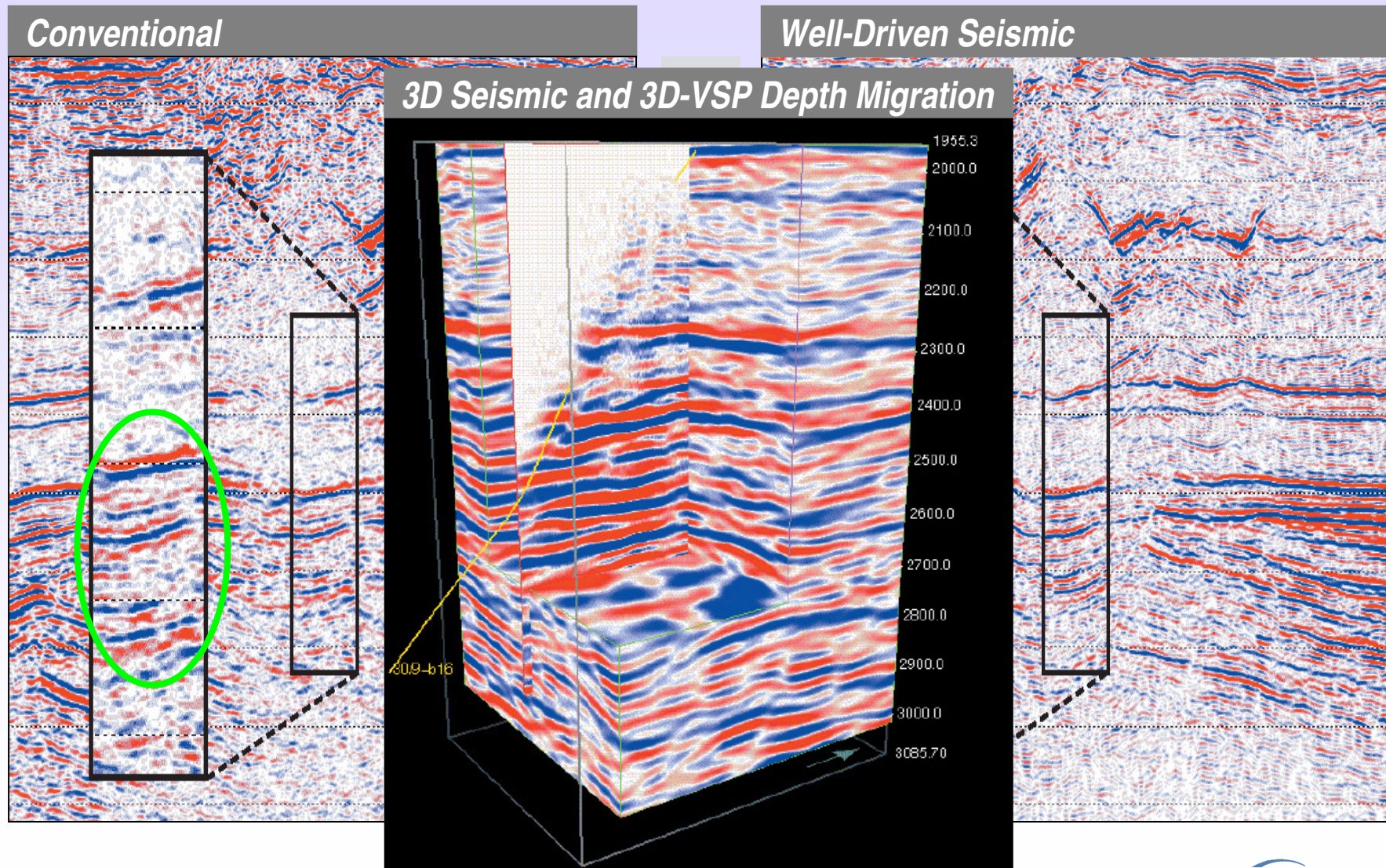
VSP Data

22



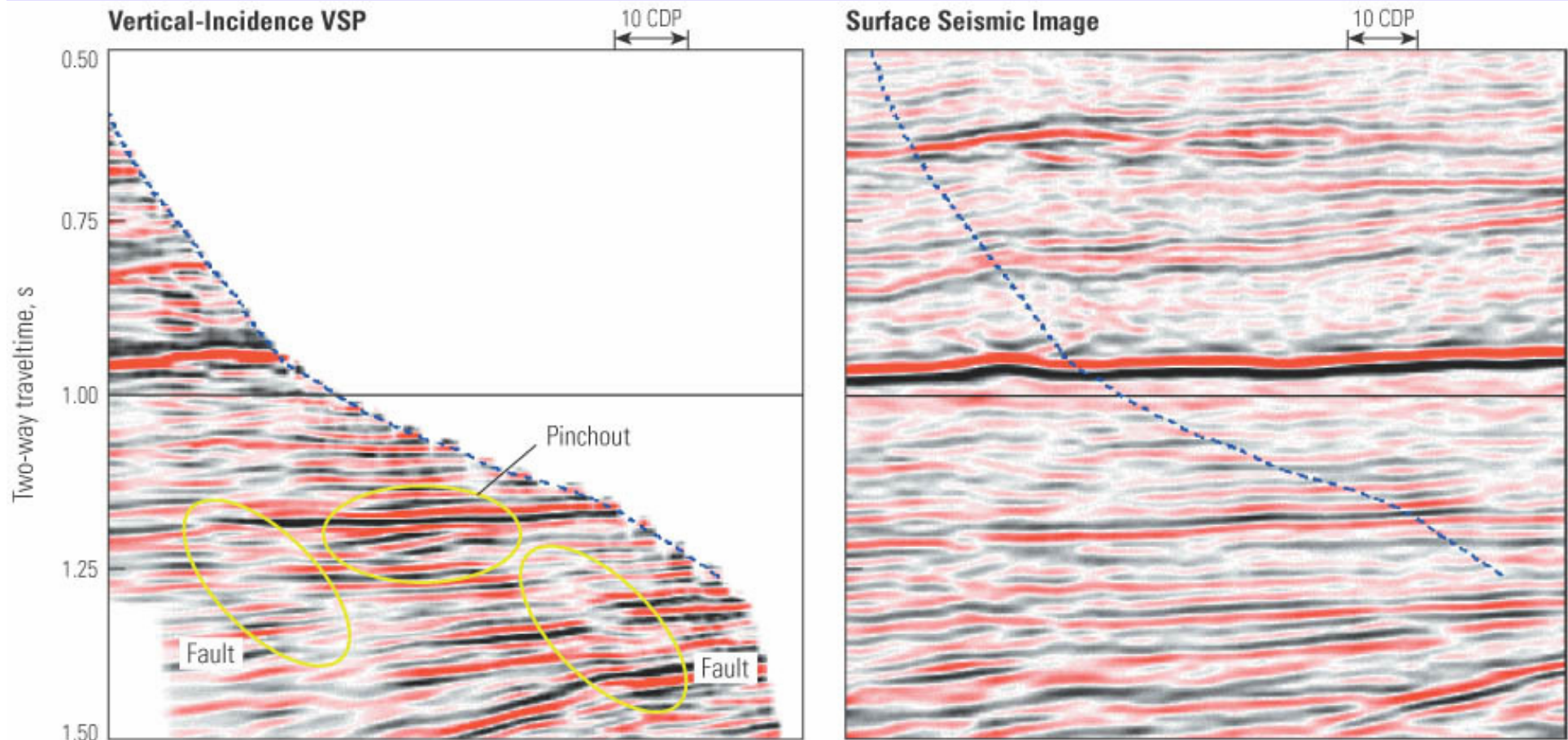
Well Driven Seismic Example

23



VSP vz surface seismic

24



Conclusions

25

Seismic Data is needed to:

- Build a detailed initial model
- Monitor CO₂ movement within reservoir
- Monitor CO₂ migration out of storage formation

Critical Factors:

- Data repeatability and noise
- Ability to resolve time-lapse signal

Storage Management:

- Reduce risk
- Optimize storage performance

Data integration:

- Surface seismic & VSP data
- Geomechanics
- Petrophysics
- Geochemistry

Questions??

